

# Spacecraft Common Deployable Boom Hinge Deploy & Latching Mechanisms

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NISAR Observatory

SWOT Observatory

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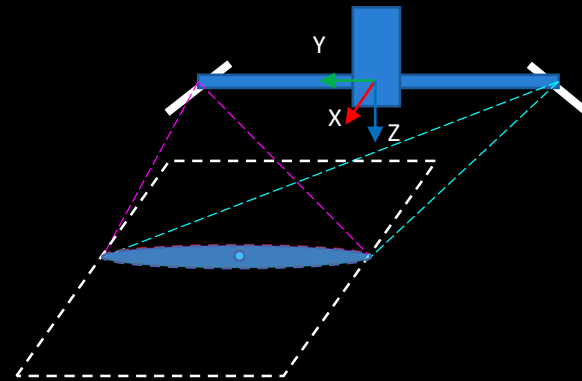
# Reflector Boom Alignment Challenge

- Radar reflector boom alignment/pointing error budget is tight (approximately  $0.0015^\circ$  max azimuth budget)

NISAR:



SWOT:



- How to design hinge deploy mechanisms that apply no significant force/torque to the boom across on-orbit thermal cycles after completion of deployment?



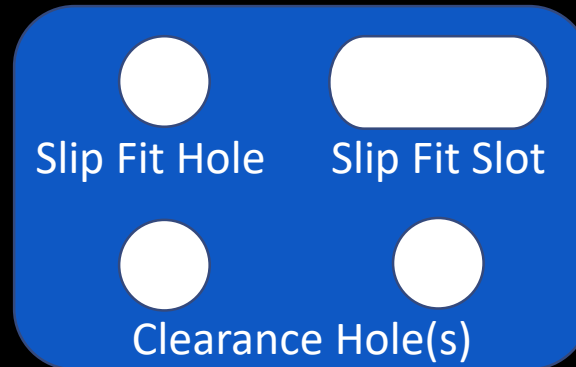
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# Thermally-Stable Boom Mechanism Design

Approach taken to avoid significant thermally induced loads:

1. Used non-preloaded shear interfaces to mount mechanisms to boom structure



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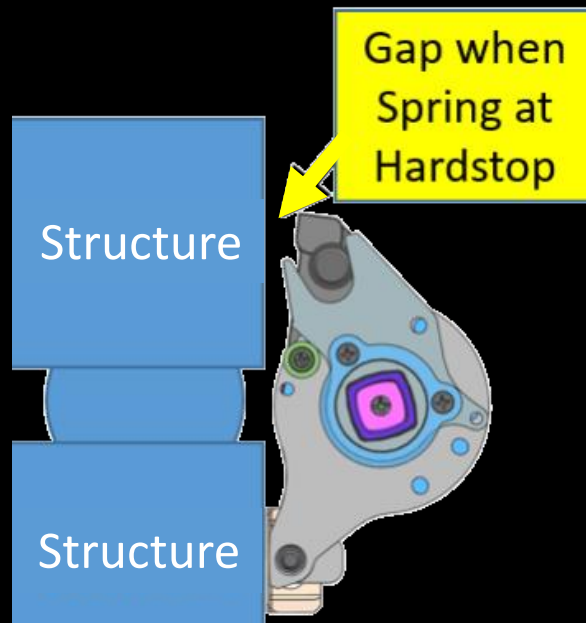
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# Thermally-Stable Boom Mechanism Design

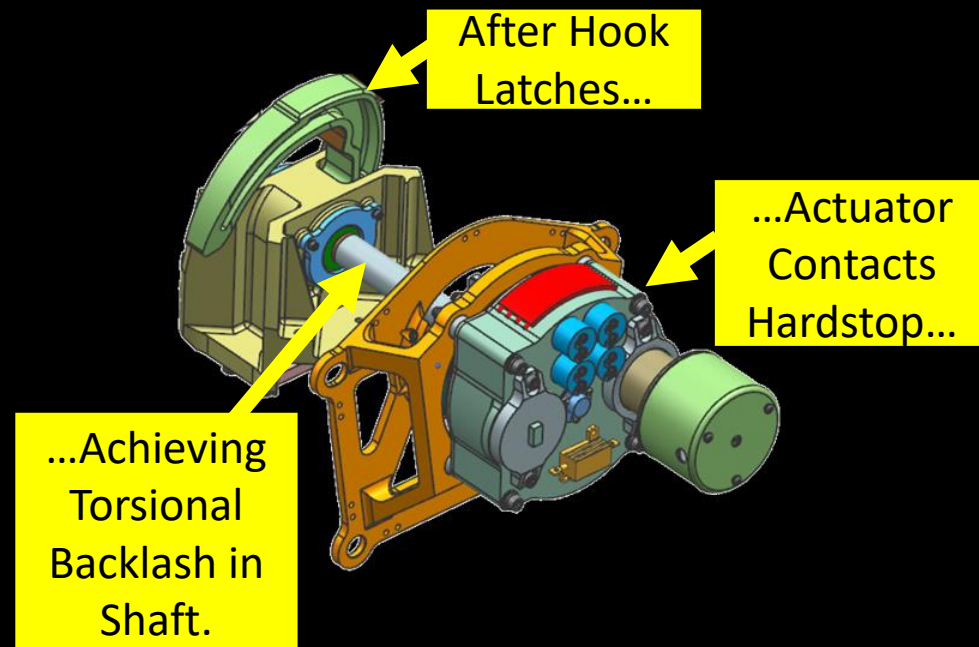
Approach taken to avoid significant thermally induced loads:

2. Incorporated backlash between driving mechanisms & deployed structure via mechanism internal hardstops

## Hinge Closure Spring



## Latch Actuator



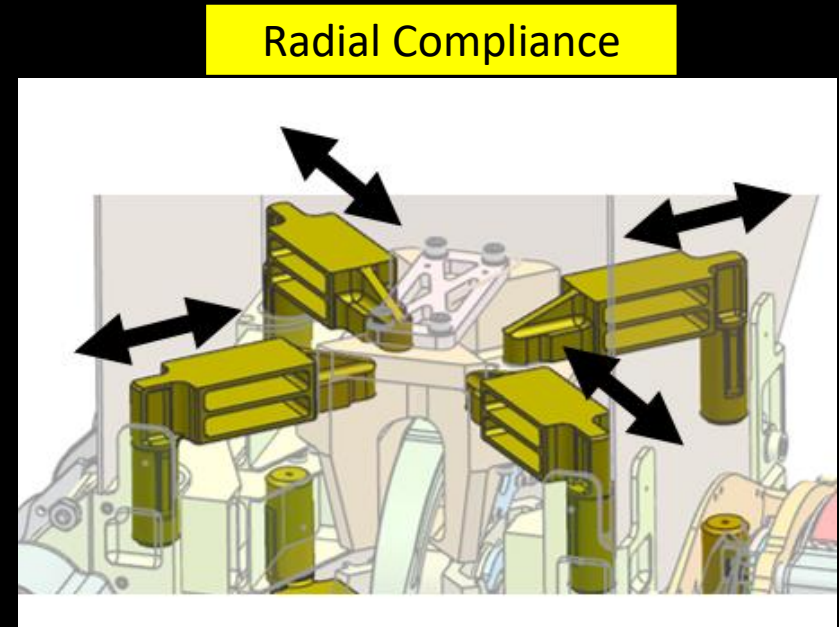
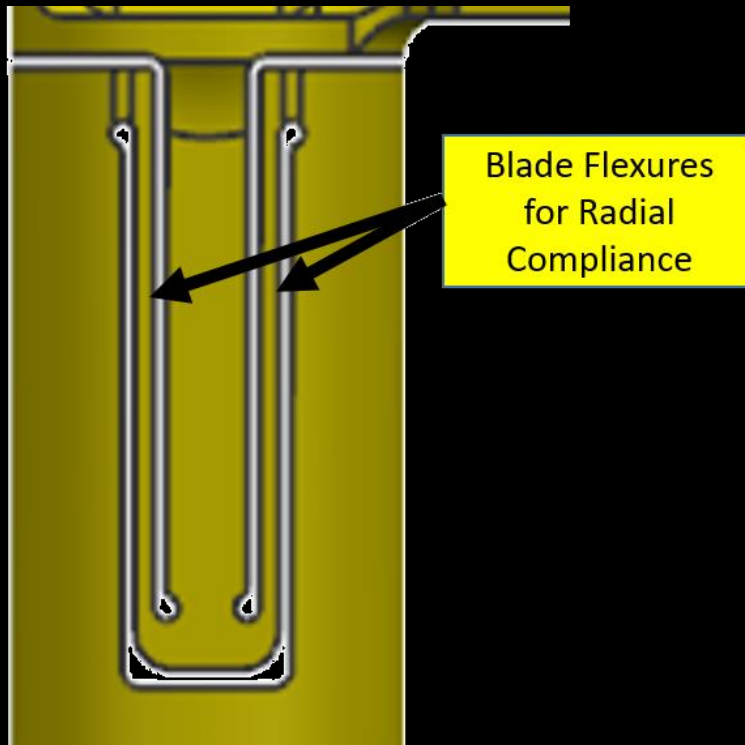
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# Thermally-Stable Boom Mechanism Design

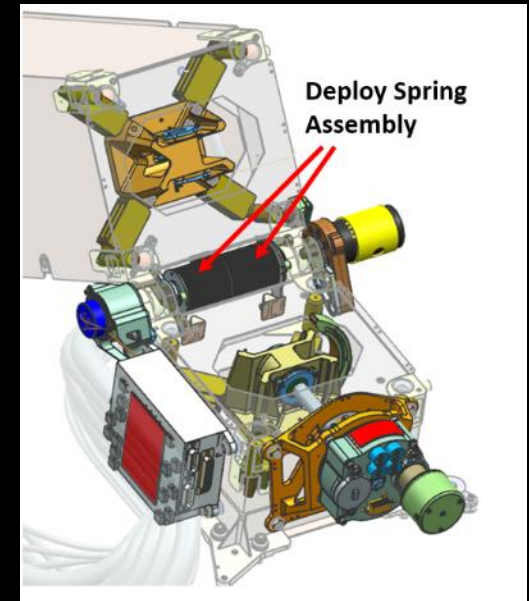
Approach taken to avoid significant thermally induced loads:

3. Used radial flexures in latch mechanism to avoid large thermally-induced loads



# Deployment Torque Challenge

- High torque needed from hinge deployment springs in small available volume
- 17-7 PH CRES round-wire springs using all available volume do not provide adequate torque
- Uh oh. What do we do?



# Rectangular Cross Section Spring Design

- Used rectangular cross section spring to maximize spring constant and minimize bending stress in volume available
- By analysis, rectangular springs provide adequate torque.
- BUT... initial test results showed significantly less torque available than predicted. Now what!?!?

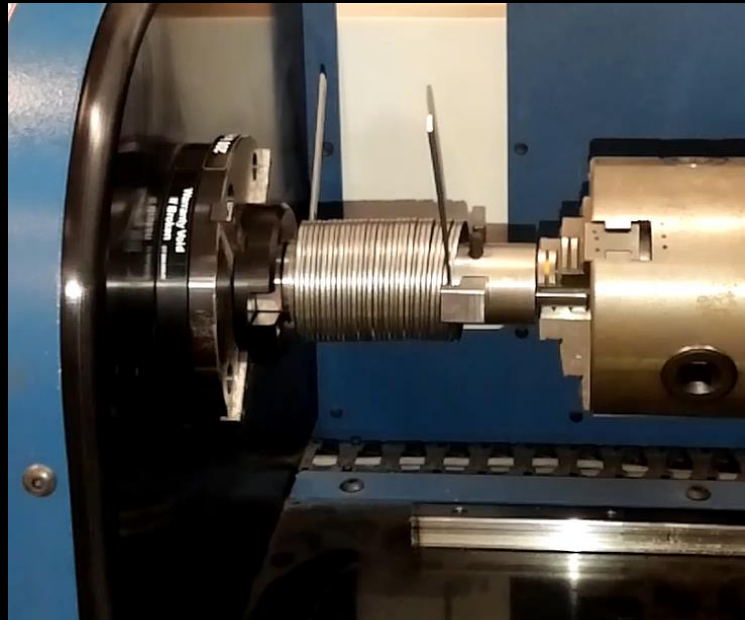


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# Rectangular Cross Section Spring Arm Twist

- The high-aspect ratio (3.8:1) rectangular spring arms were twisting about their centerline, reducing spring stiffness at high deflections
- Support guide slots were added to each spring arm substantially reducing this twist. Subsequent test results matched predictions.



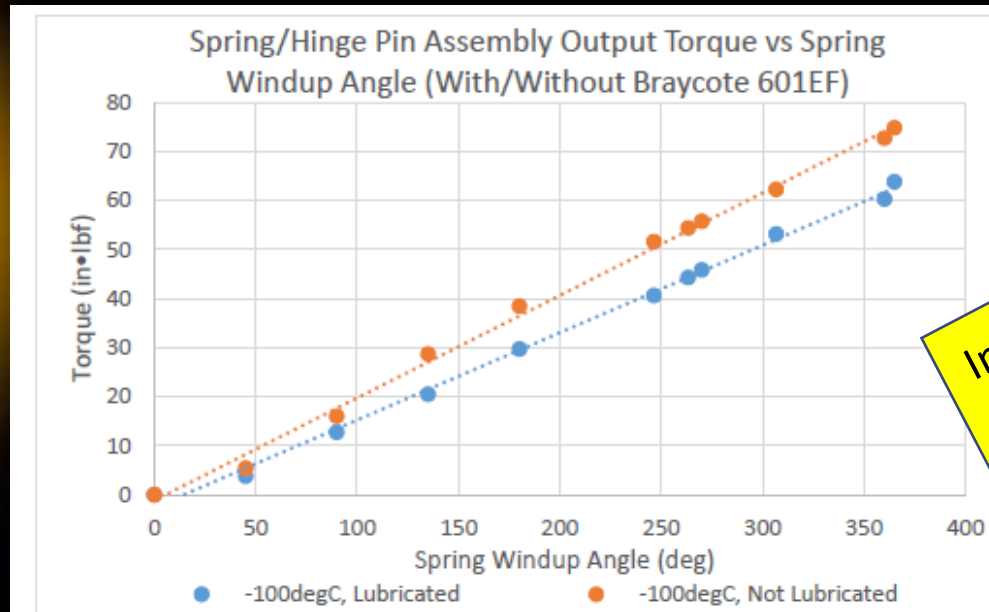
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# Spring Lubrication

- Maximum required deployment torque is in the qualification cold thermal environment.
- In this environment, even a thin film (grease-plated) Braycote 601EF proved detrimental to spring output torque when compared to unlubricated 17-7 PH CRES
- Dry film lubrication not tested. Opportunity for follow-on testing!



Intuition Corrected By  
Test Results...Again

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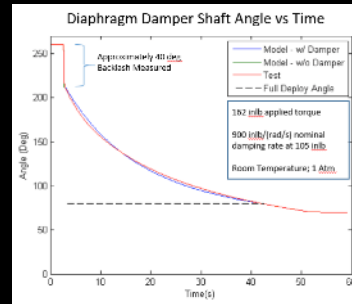
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# Issues with Elastomeric Diaphragm Dampers

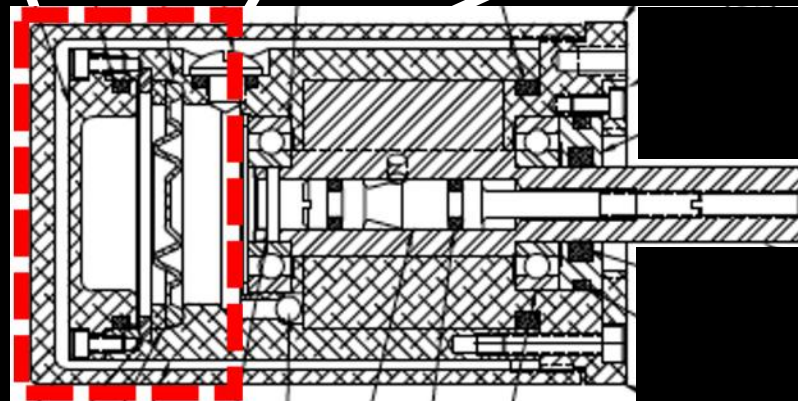
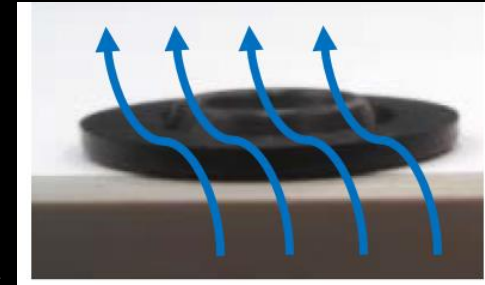
## Permanent Deformation of Diaphragm



## Long Fluid Recovery Time & Internal Backlash



## Elastomer Permeability



## Elastomeric Diaphragm Damper

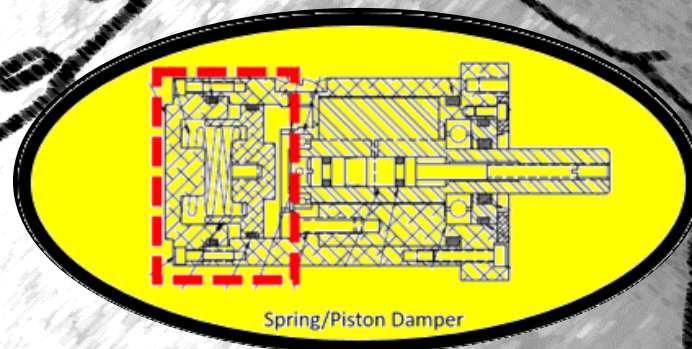


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# Spring/Piston Damper

**TO THE RESCUE!**



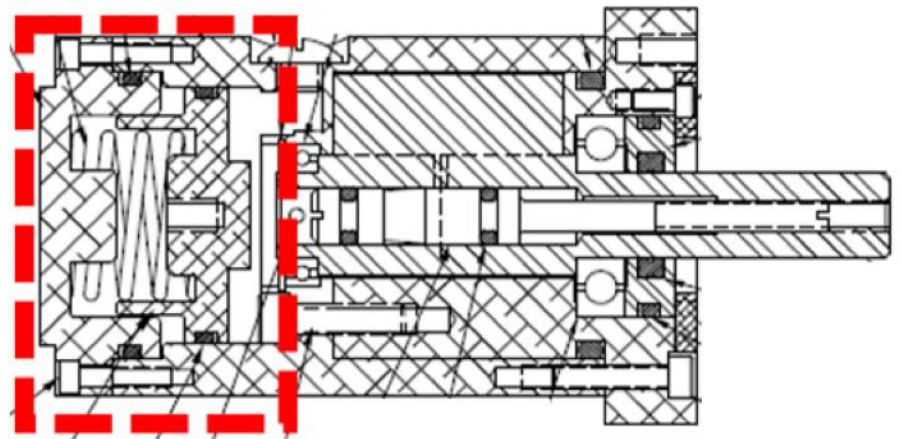
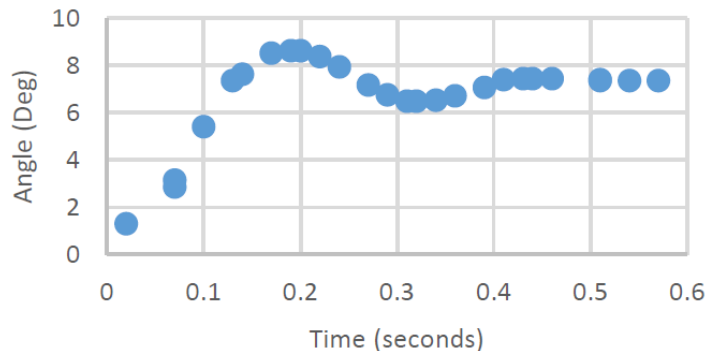
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# Spring/Piston Damper

- Spring/Piston Damper testing demonstrated:
  - Zero measured internal backlash
  - Superior damping rate linearity
  - Robustness to high impulse torque application
  - Rapid fluid recovery time

Prototype Damper Impulse Test Response  
1060 inlb Applied for 6.3 deg, -15degC, 1  
Atm



Spring/Piston Damper



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# Damping Coefficient Variability

- Ideal Damper: 
$$T_{Damper} = c \cdot \dot{\theta} + T_{Coulomb}$$
- Real damping coefficient varies significantly with applied torque and fluid temperature
- Factor of 5x difference in damping constant between initial Qual Cold and Qual Hot operational temperatures at low applied torques.
- Damper heaters incorporated into design to control damper temperature

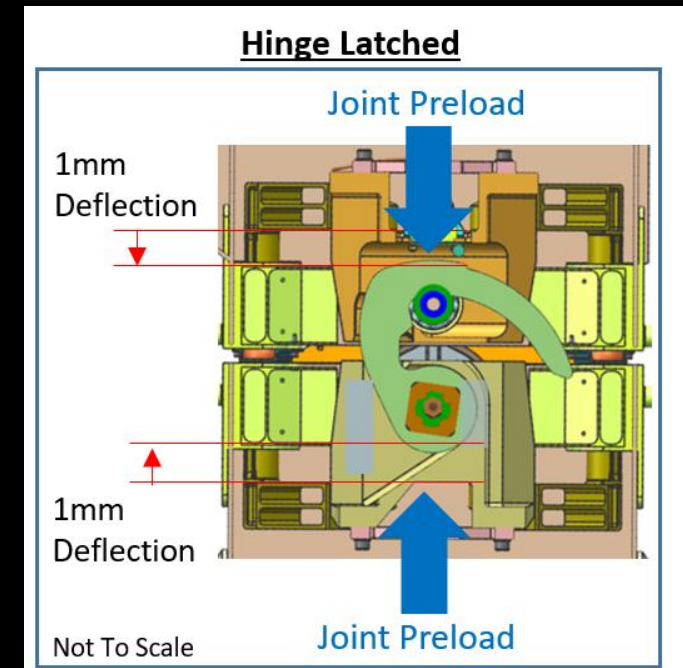
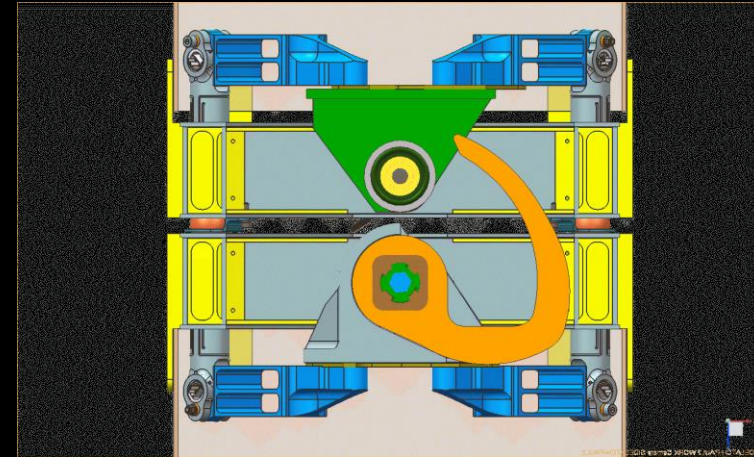


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# Hinge Latch Hardware: Key Points

- Parabolic hook profile used; requires constant torque throughout latching (minimizes peak torque required)
- Latch structure flexured in preload direction to achieve large deflection at target preload
- Large deflection reduces preload variability due to small relative dimensional changes across the range of mission temperatures



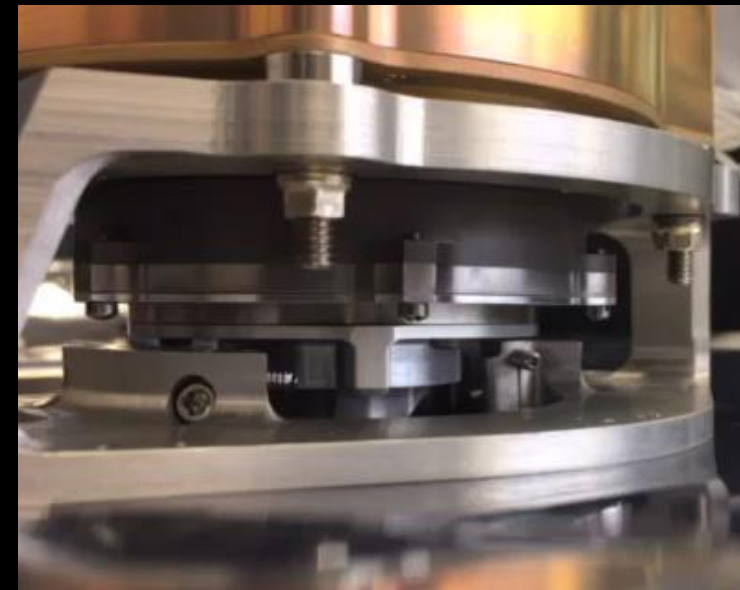
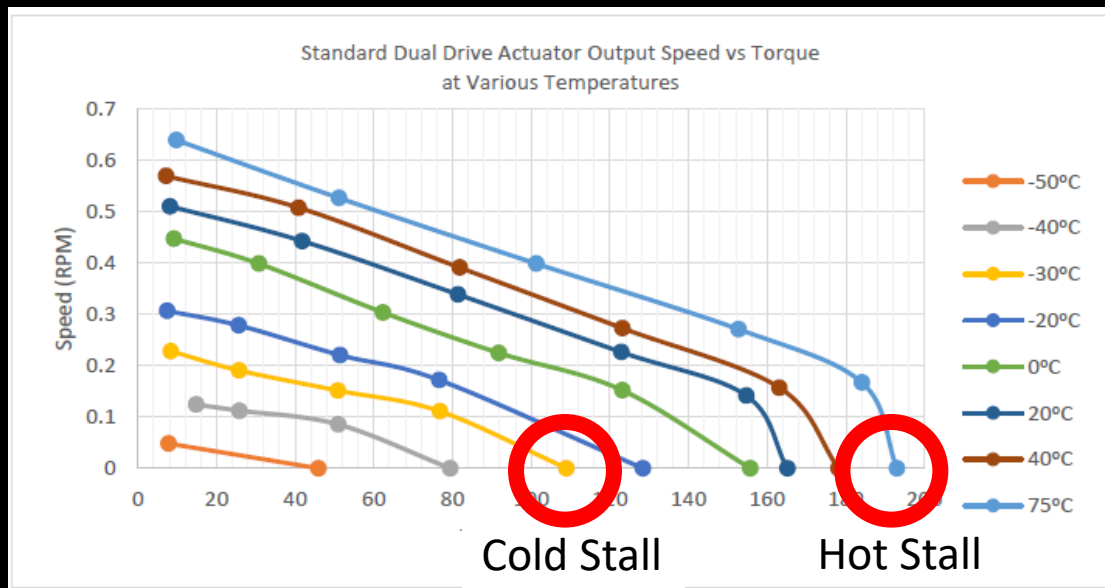
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# Actuator Performance Challenge

- Maximum latch actuator stall torque set just below harmonic gearset ratchet torque. Occurs at highest operational temperature.
- Significantly lower stall torque available at coldest operational temperature (43% reduction).

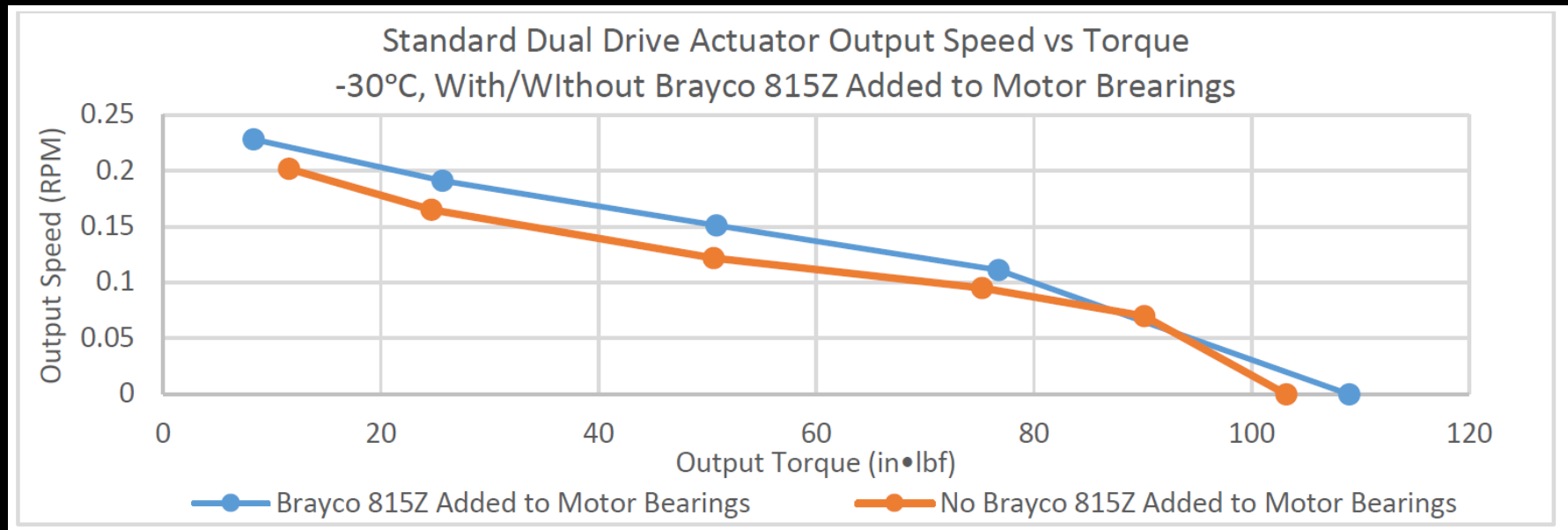


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# Increasing Actuator Minimum Output Torque

- Actuator output torque was measured at -30°C with:
  - Motor bearings grease plated with Braycote 601EF
  - Motor bearings grease plated with Braycote 601EF with additional Brayco 815Z added
- Test results show slight increase in output torque with the Brayco 815Z added



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# Summary of Key Lessons

- Mechanical decoupling of mechanism hardware from alignment critical structures is a robust and effective approach to avoidance of mechanism-induced thermal distortions
- High aspect ratio rectangular wire torsion spring arms must be adequately supported to prevent undesirable twist along the wire axis when used at significant angles of deflection.
- The spring/piston viscous damper design described in this document provides performance benefits over heritage elastomeric diaphragm dampers.
- The addition of Brayco 815Z to Braycote 601 lubricant provides measurable improvement in cold temperature ball bearing performance.



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